LS-36
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Field Calculations of the Booster Dipole and Quadrupole Magnets

Two dimensional magnetic fields of the booster dipole and quadrupole magnets were calculated using the computer program POISSON. The magnet parameters used for the calculation are based on L. Teng's note (8/12/85) and listed in Table 1.

Table 1
Booster Magnets

Dipole		Quadrupole	
Gap	±2 cm	Pole Contour	$xy = 4\ cm^2$
Pole Width	±5 cm	Pole Width	4.24 cm
Coil Cross-Section	$3.5 \times 5\ cm^2$	Pole Tip Corner (x,y)	(1,4) and (4,1)
Good Field Region	± 2.8 cm wide	Coil Cross-Section	$2.4\ cm^2$
	± 2.0 cm high	Good Field Region	1.4 cm radius
Yoke Thickness	5 cm	Overall Dimension	$23.5 \times 23.5\ cm^2$
Overall Dimension	$21 \times 30\ cm^2$	B' max	150 kG/m
B Max	7 kG	B max	6.2 kG
NI	11141 A	NI	4775 A

Dipole Magnet

The triangular mesh with the physical (x,y) and logical mesh (K,L) coordinates for the field calculation is shown in Fig. 1. The distortion of the mesh near the point of (x = 5, y = 2) is the field correction shim. Since the dipole is symmetric with respect to the x- and y-axis, only a quarter of the cross-section is used for the computation.

Figure 2 shows the field lines in one quarter of the dipole. A built-in B-H curve for 1010 Steel is used for the calculation. The field correction shim shown at the pole tip has a dimension of 1.25 cm wide and 0.079 cm thick. With a central field of 7 kG, the average field in the shim is 14 kG. The fields in the side and top yoke are 5 ~ 12 kG. The stored energy for this magnet is 270 Joules/meter and must be multiplied by four for the effective length of the whole magnet.

Table 2 is the harmonics calculated by integrating the vector potential on a radius of 1.75 cm around the origin and normalized at the radius of 2.0 cm. The A_{N-1} are the coefficients of a Maclaurin series expansion of the field.

Table 2
Dipole Harmonics (R = 2.0 cm)

N	B_N (Gauss)	A_{N-1}
1	6.973×10^{3}	6.973×10^{3} G
3	9.23×10^{-2}	4.61×10^{-2} G/cm^2
5	-1.59×10^{-3}	-2.39×10^{-3} G/cm^4
7	-3.09×10^{-1}	-3.48 G/cm^6
9	-2.66×10^{-1}	-4.19×10 G/cm^8

Quadrupole Magnet

The triangular mesh with its coordinates (u-v and K-L) of Fig. 3 represents 1/8 of the quadrupole cross-section. The 1/8 of the quadrupole cross-section in the z = x + iy plane is transformed into one quarter of a dipole in the w = u + iv plane by the transformation:

$$w = z^2/2R_o,$$

where R_o is the magnet bore radius (see LS-32).

Figure 4 shows the field lines of 1/8 of the quadrupole in the w-plane. The straight line of v = 1.41 cm corresponds to the pole contour of xy = 4 cm^2. The dimension of the steel shim in the w-plane is 0.6 cms 0.09 cm. Figure 5 shows the shape of the magnet and the shim in the z-plane. In the yoke, the field is 4.9 kG and in the shim 10.8 kG. The stored energy is 48 J/m for 1/8 of the magnet.

The harmonic analysis of the corrected field is shown in Table 3. In order to estimate the error of the calculation, harmonics for a perfect dipole are calculated using the same number of mesh points and the same shape

Table 3
Quadrupole Harmonics (R = 1.5 cm)

N	B_N (Gauss)		A_{N-1}
	Transformed Quadrupole	Perfect Dipole	
2	4.236×10^{3}	4.236×10^{3}	1.498×10^{3} G/cm
6	7.92×10^{-3}	-1.88×10^{-4}	1.24×10^{-1} G/cm^5
10	-1.92×10^{-2}	2.10×10^{-6}	1.82×10^{2} G/cm^9
14	-2.47×10^{-3}	6.33×10^{-7}	-7.91×10^{4} G/cm^{13}
18	-1.25×10^{-4}	-1.75×10^{-7}	-4.51×10^{7} G/cm^{17}

in the region of the magnet bore radius. Those errors are negligible compared to the harmonics in the transformed quadrupole. In Table 3 the 2nd harmonic is calculated at the pole tip and all the higher harmonics are at R = 1.5 cm. Also, it has been found that the error of the field gradient within the radius of 1.5 cm is on the order of 10^{-4}.

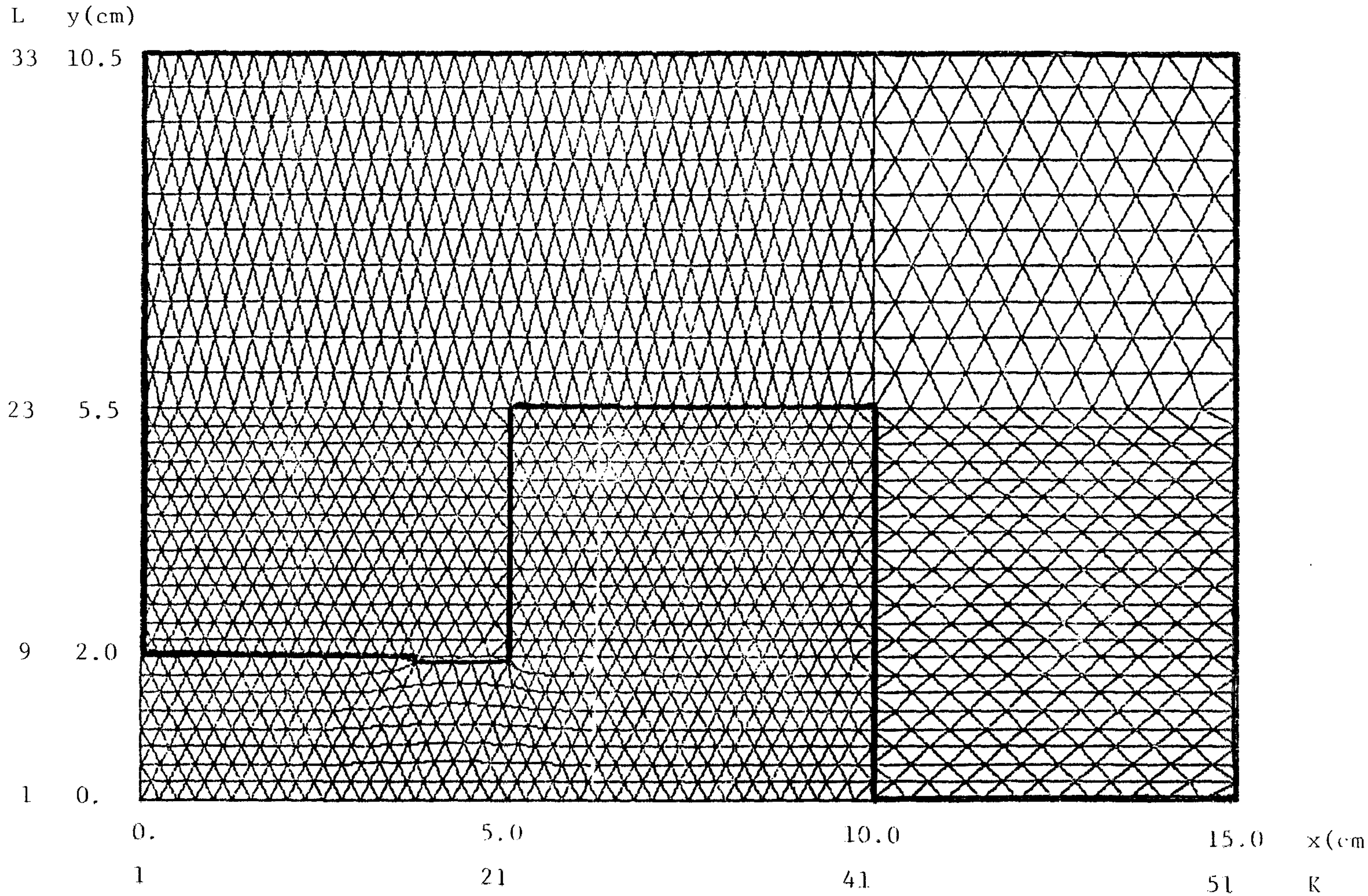

Fig. 1. Mesh and Coordinates of the Dipole

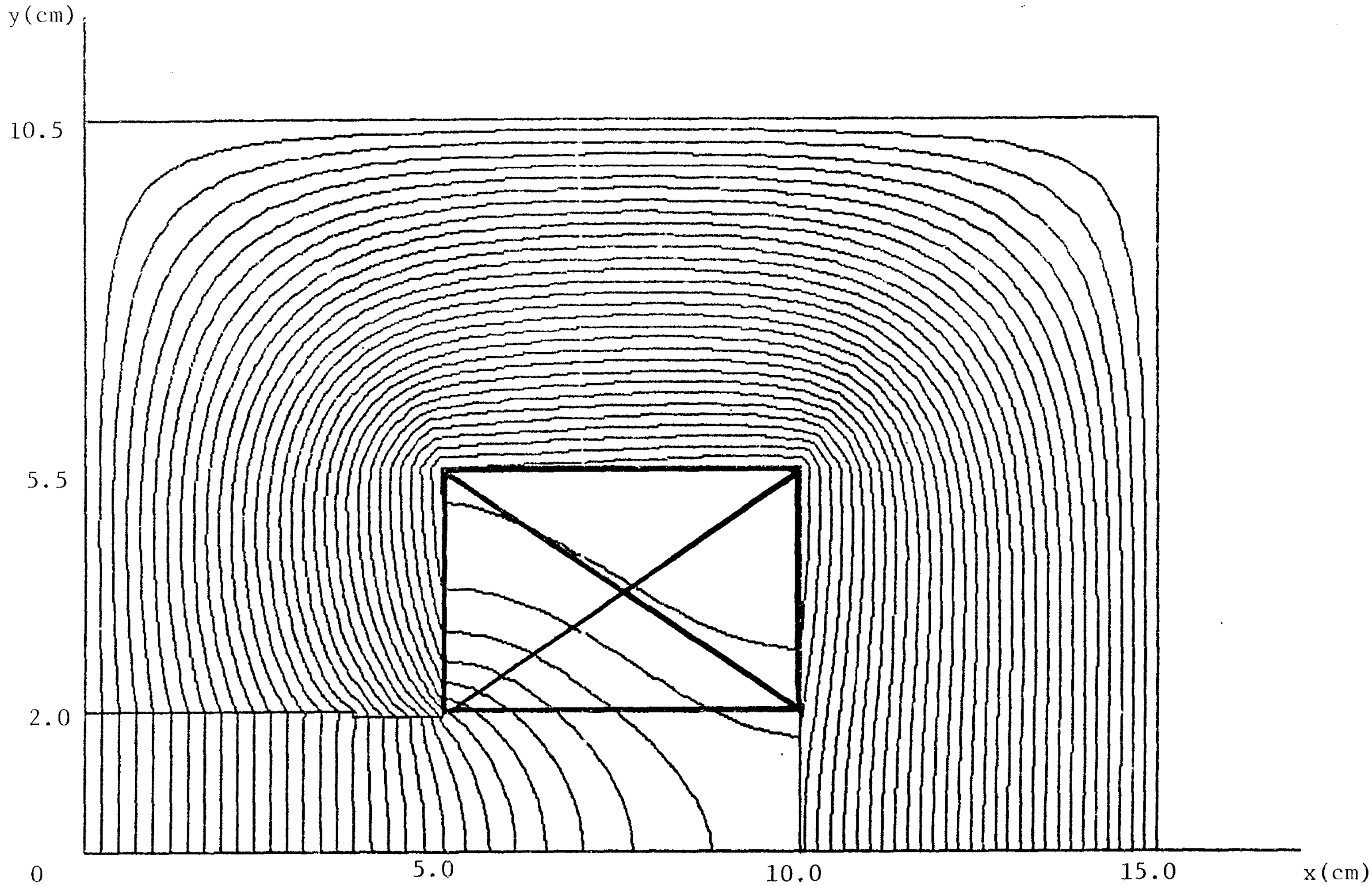

Fig. 2. Field Lines in the Dipole

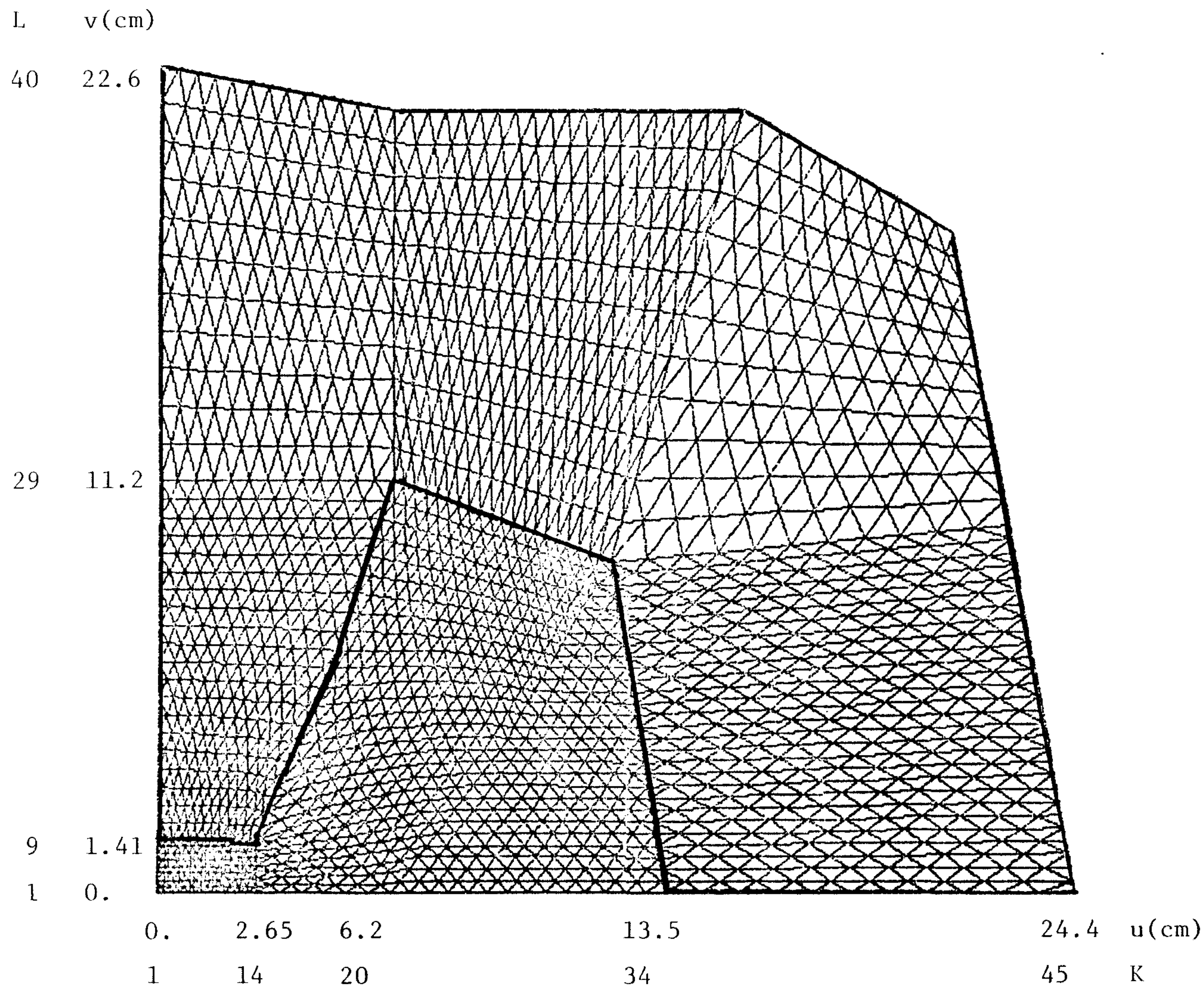

Fig. 3. Triangular Mesh in (u-v) and (K-L) Coordinates of the Quardupole

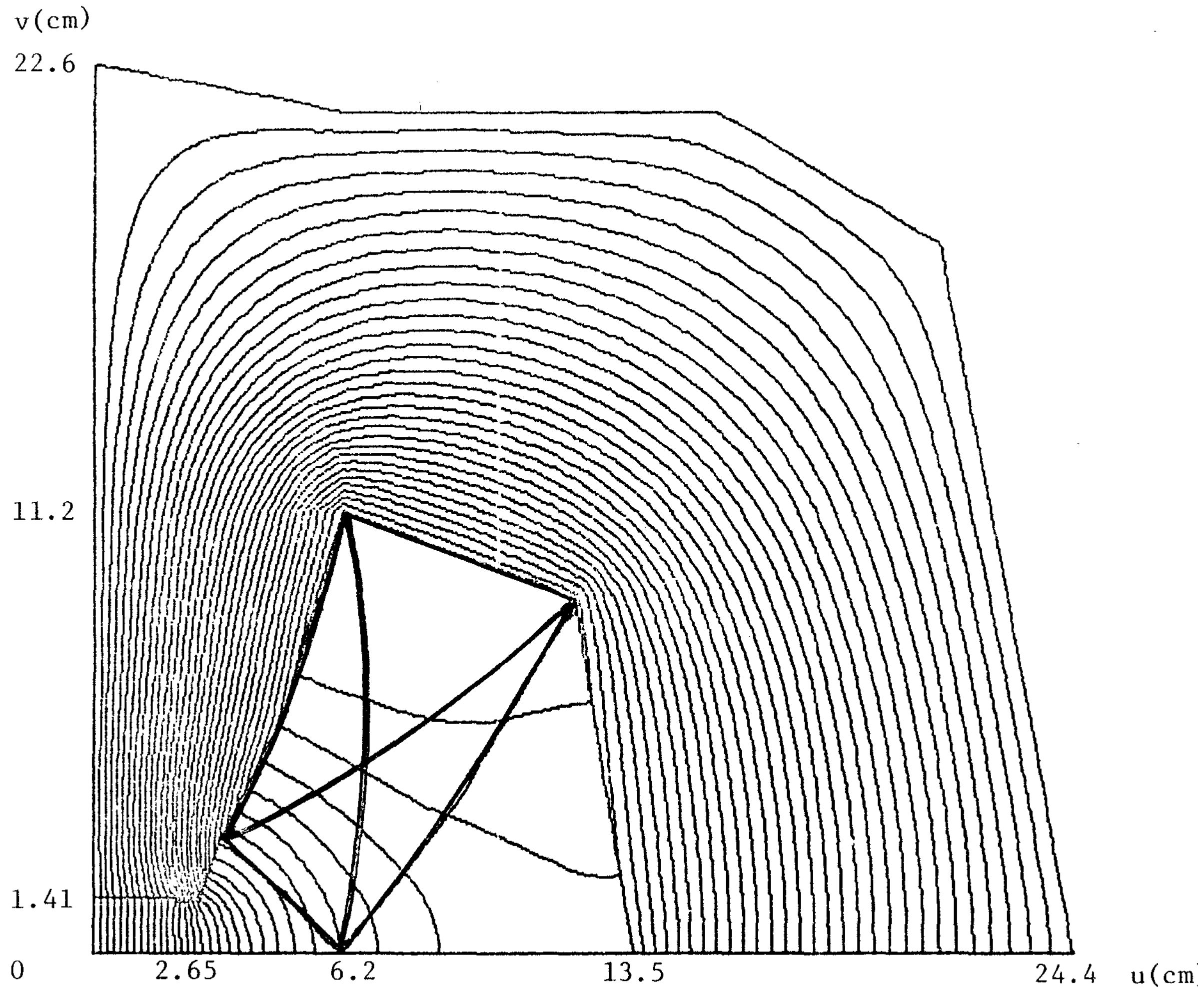

Fig. 4. Field Lines of the Quadrupole in (u-v) Coordinate

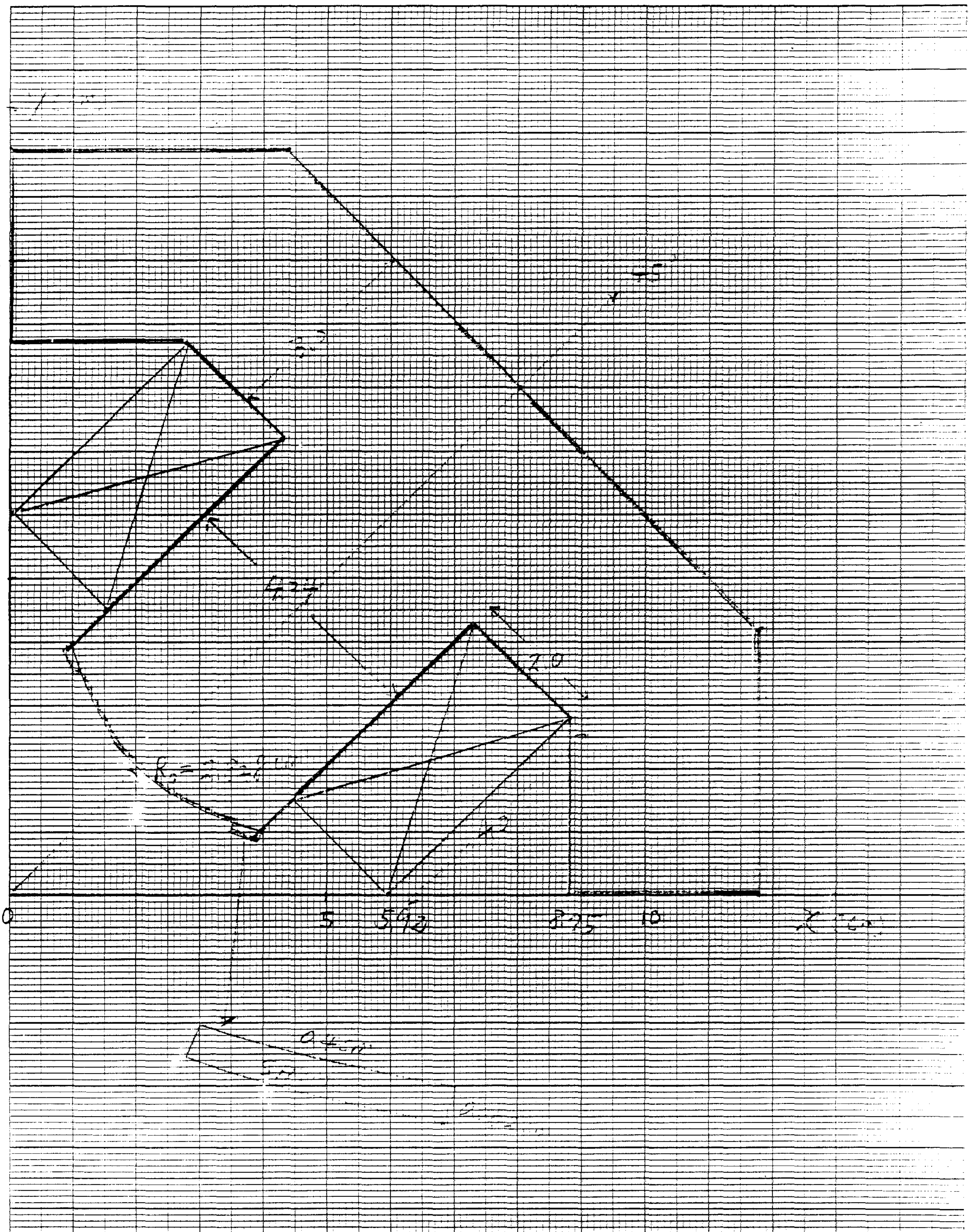

Fig. 5 Quadrupole [illegible]